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Abstract

REACTOR DIRECT-CONVERSION UNITS

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The objective of the United States Atomic Energy Commission's SNAP, Systems for Nuclear Auxiliary Power Reactor Program is to make compact, high-powered, long-lived, power sources available for the utilization of space through the application of nuclear heat sources. The program encompasses reactor powered units with both direct and dynamic power conversion in the subkilowatt to megawatt range of electrical power. The detailed objectives of the space application, i.e., launch ruggedness, high vacuum, zero gravity, radiative heat rejection, micrometeoroids, minimum weight, reliability, long life, and safety impose unique requirements on the reactor heat source and the power-conversion concept selection, design, development, flight qualification, and application integration.

A major initial objective of the SNAP program is the development and demonstration of the 500-watt thermoelectric system, SNAP 10A. The SNAP 10A system employs a 250 lb (114 kg) reactor having a homogeneous core of fully enriched U-235 and zirconium hydride moderator (H/U = 50) and a thin 2 in. (5.1 cm) Be reflector annulus which includes provisions for reflector geometrical variations for reactor control. After startup in orbit, the reactor is inherently self controlled during its lifetime by its negative temperature coefficient of reactivity. The reactor power of 35 kW(th) at an outlet temperature of 1000F (540C) is coupled to the thermo-electric converter by a NaK-78 heat-transfer loop. The pumping power (6.5 watts) is provided by a thermocouple-powered dc conduction electro-magnetic pump. The thermoelectric converter consists of 1440 couples of doped Si-Ge alloy ($Z = 0.65 \times 10^{-3}$ C-1) which are electrically connected into a series parallel circuit to provide

500 watts at 28 volts dc.

The hot junction of the thermocouples is electrically insulated from, but thermally bonded to, pipes containing the NaK-78 coolant at an average temperature of about 950F (510C). The cold junction of the thermo-couples is formed by 1440 individual aluminum radiator platelets. Heat rejection to space from the 62.5 ft.2 (5.8 m2) of integrated radiator area of these platelets maintains the cold junctions at an average temperature of 615F (325C). The complete SNAP 10A system weighs 950 lb (430 kg) which includes 215 lb (98 kg) of LiH shadow shield to reduce the radiation dose at the payload interface to less than 10^{13} nvt and 10^{8} rads per year. The system is approximately conical in shape, 5 ft. (1.5 m) in diameter by 12 ft. (3.65 m) high, with the reactor at the apex and the integral thermoelectric converter radiator located on the outer surface of the cone. The program is in the final stages of ground demonstration and pre-flight qualification.

The initial conceptual design studies for nuclear space power began in 1953. The SNAP hydride-reactor concept was chosen in 1955 on the basis of minimum weight, applicable temperature capability, and reactor and materials state of the art. The program achieved development status in early 1957 and reactor concept verification was accomplished with a critical assembly in October 1957. The initial SNAP system concept utilized a mercury Rankine cycle for power conversion. A continuing objective of the SNAP program is to develop the reactor and rotating machinery technology necessary to realize the performance advantages of mercury Rankine-cycle systems. In the program to date, two power test reactors have operated at the 50 kW(th) and 1200F (650C) requirements of a 5-kW electrical mercury Rankine system and a third reactor is operating at the 450 kW(th) and 1300F (705C) requirements of a 35 kW(e) system.